TwoStage gasification of biomass for clean syngas: Technology and applications

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TwoStage gasification of biomass for clean syngas: **Technology and applications**

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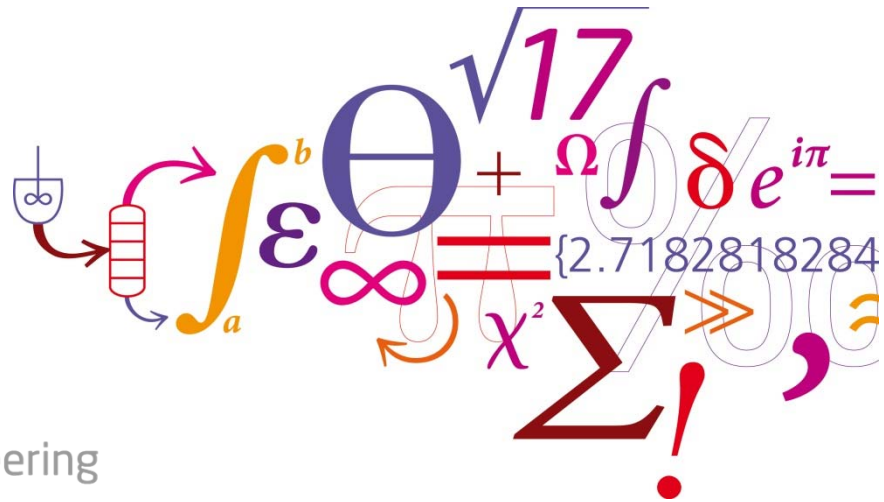
DTU Chemical Engineering



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Department of Chemical and Biochemical Engineering

DTU IEC 2013 | Agenda

- Presenting **The Biomass Gasification Group**
- Describing **TwoStage downdraft gasification technology and gas characteristics**
- Examples **Application of clean synthesis gas**

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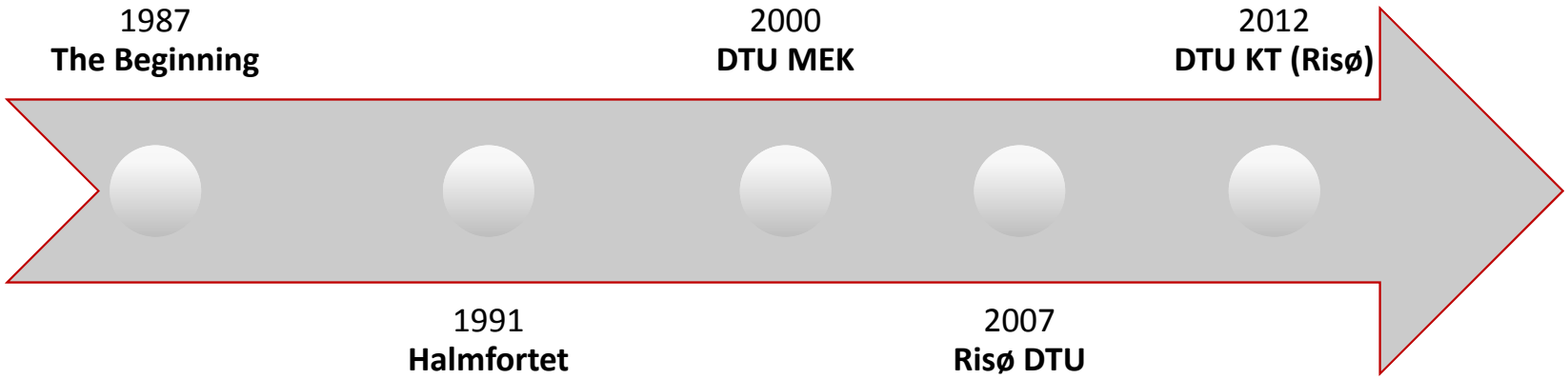
HISTORY

Biomass Gasification Group | History



BGG History | History & Results

20 years of research, development and demonstration has resulted in **two pre-commercial gasification processes:**

1. **The TwoStage gasifier**, a high temperature process for gasification of wood (developed in cooperation with COWI)
2. **The PYRONEER gasifier** (Low Temperature Circulating Fluid Bed), a low temperature process for gasification of low grade biomass e.g. straw, manure and waste (developed in cooperation with Danish Fluid Bed Technology)

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FACILITIES

BGG Facilities | DTU Chemical Engineering (KT)

Lyngby

Risø

BGG Facilities | BGG at DTU KT (Risø)

BGG Facilities | Building 313

PHYMLAB

Physical and mechanical testing

Grindability
Pelletization
Humidification
Drying
Sampling
Etc.

CHEMLABs

Chemical and analytical testing

GC
HPLC
Extraction
M-TGA
Heating value
Etc.

BGG Facilities | Building 321

THERMOLAB

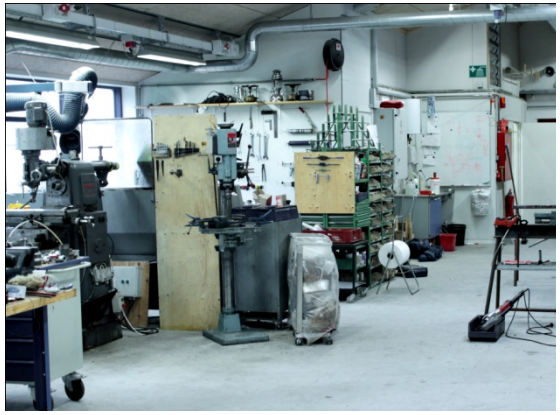
High temperature testing

Macro-TGA
Pyrolysis
Torrefaction
Drying
Annealing
Etc.

WORKSHOP

Preparation and large scale testing

Welding
Cutting
Construction
SOFC setup
LT-CFB setup
Etc.



Technology description

TWO-STAGE THERMAL GASIFICATION OF BIOMASS

Gasification | TwoStage Gasification

Gasification | TwoStage Gasification

The Viking TwoStage Gasifier

- Small scale fixed-bed two-stage CHP(70 kW fuel)
- Commissioned August 2002
- Fully automated and unattended operation
- 4004 (3600) hours of operation

Gasification | TwoStage Gasification

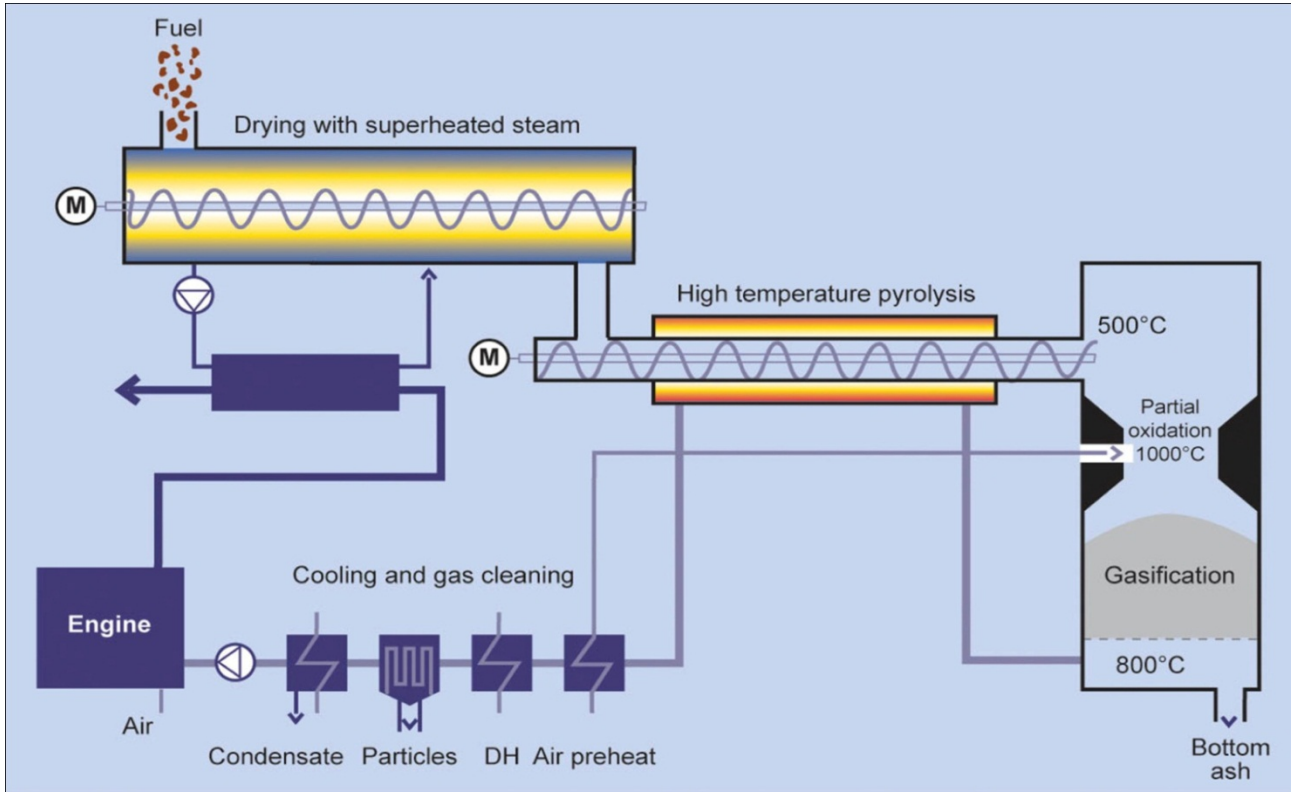
TwoStage downdraft pilot plant at Weiss A/S

VIKING **1:1**

Pilot plant at Weiss A/S **1:10**

Gasification | TwoStage Gasification

Up-scaling of TwoStage downdraft gasification for CHP production: Hadsund/Hillerød, Denmark



Courtesy Weiss A/S

Gasification | TwoStage Gasification

Weiss A/S, DTU KT and **COWI** have designed and build a **500 kW_{el} gasifier** in the city of Hillerød.

The plant will operate as a combined heat and power plant, producing heat for households and electricity for the grid.

1000 hours of operation during commissioning

TwoStage Gasification | Perspectives

- High gasification efficiency > 93%
- High electrical efficiency >40% with gas engines
- Potential electrical efficiency ~50% with SOFC
- Ideal for decentralised combined heat and power production (CHP)
- High total efficiency (CHP mode) >100%

TwoStage Gasification | Gas characteristics

- Permanent gas species composition:

Gas species	CO	CO_2	H_2	CH_4	N_2
Vol%, dry	19.6	15.4	30.5	1.2	33.3

Gas from the Viking gasifier operated on pine wood chips. Ahrenfeldt et al., 2006

- LHV_{gas}: 5-6 MJ/Nm^3 Ahrenfeldt et al., 2006
- Tar content: 0.02-0.1 mg/Nm^3 naphthalene only, Ahrenfeldt et al., 2006
- Suitable for SOFC operation, 150 hours single cell test completed

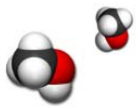
Technology description

APPLICATION OF SYNGAS FROM TWOSTAGE GASIFICATION

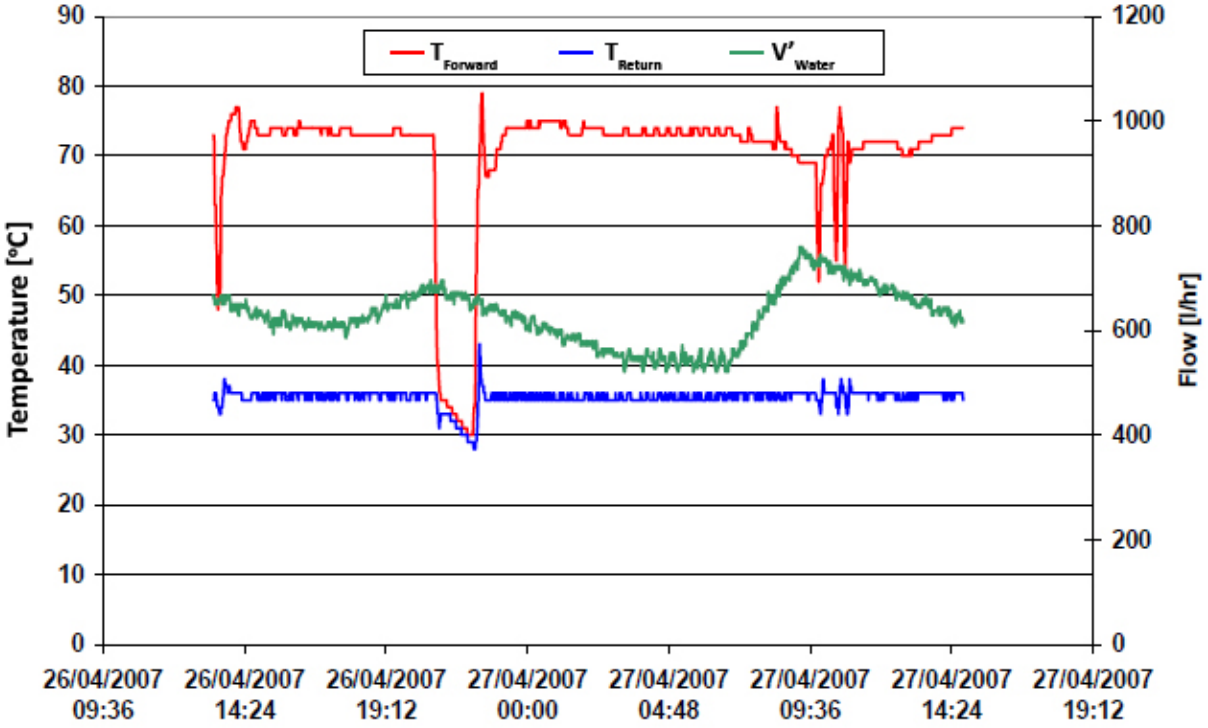
TwoStage Gasification | Gas application

1. Cogeneration of **heat and power**

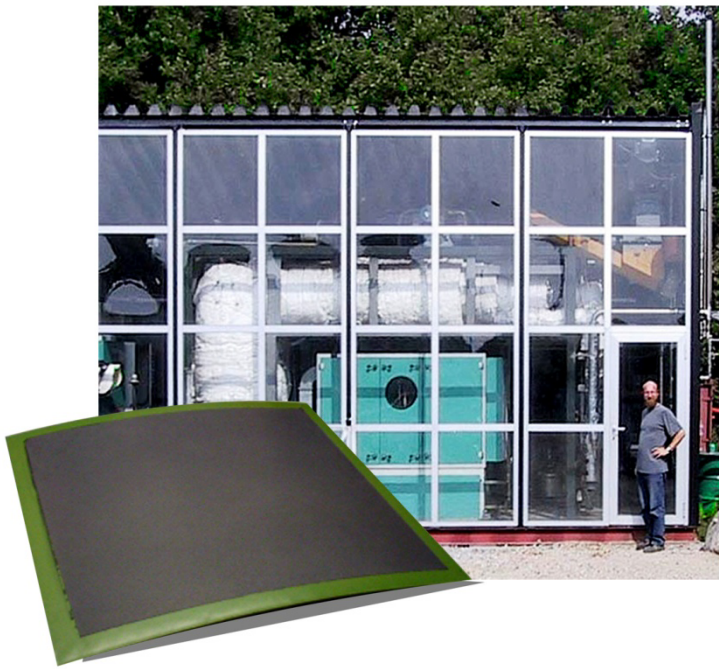
2. Polygeneration of **heat, (power) and biofuels**



Gas application | Flexible CHP



Gas application | CHP production via SOFC



Extremely clean producer gas

Single cell test successful in 2006
(150 h without catalyst degradation)

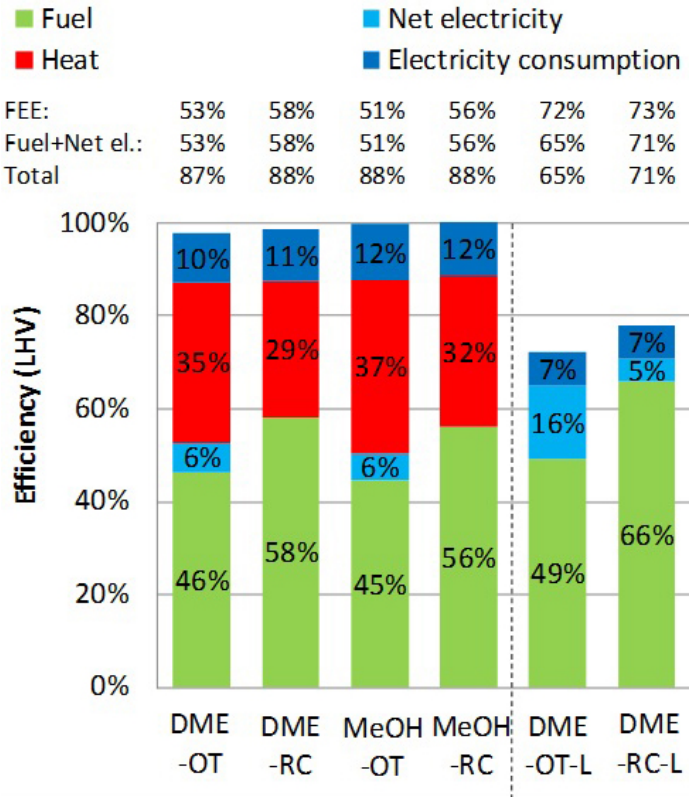
2 kW stack test starting up 2013

Model results on 500 kW gasifier:
Micro gas turbine (MGT): 28% el / 76% CHP
SOFC: 36% el / 80% CHP
SOFC + MGT: 50% el / 80% CHP

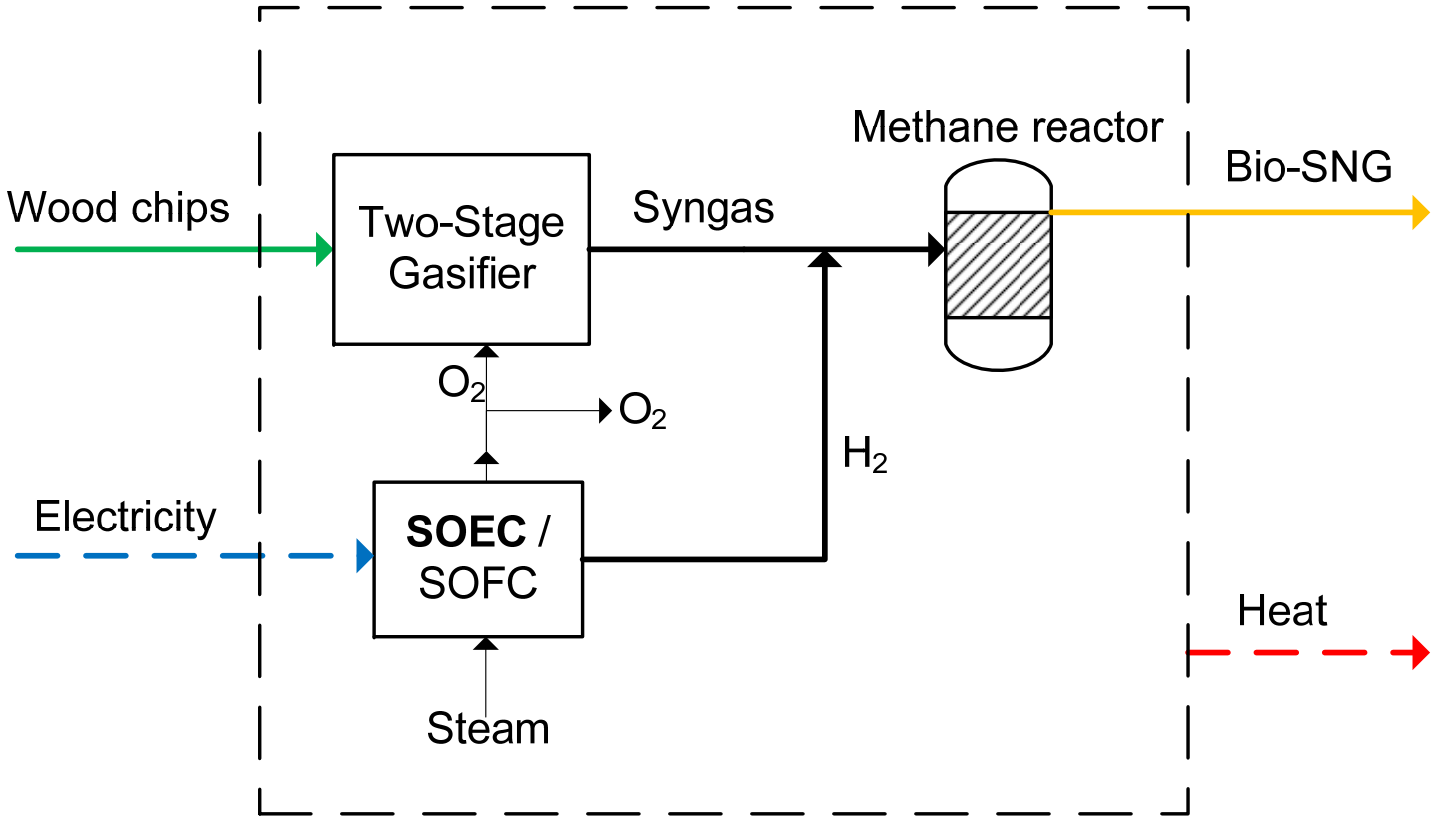
Gas application | Bio-methanol/DME

Thermodynamic model of process:

- 5 MW_{TH} input
- Feed stock: Wood chips
- Gas composition as Viking pilot plant
- Once-through >< Recycling plant
- Trigeneration of liquid fuel, power and district heating
- Compared to large, centralized plants



Gas application | BioSNG (Synthetic Natural Gas)



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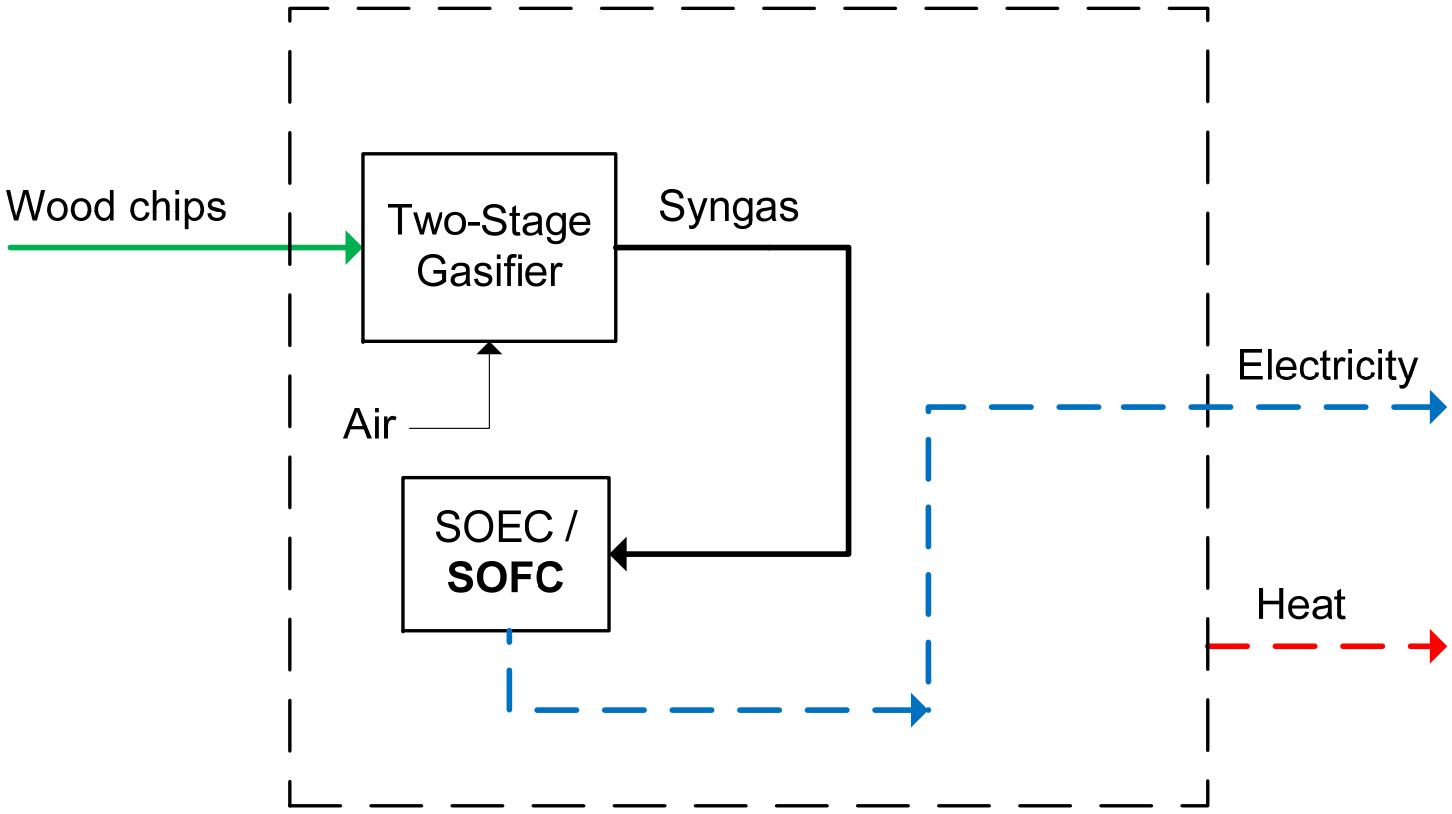

Gas application | BioSNG (Synthetic Natural Gas)

Plant efficiency estimations by DNA modeling (three designs):

- Biomass-to-SNG efficiency based on LHV: **65-78%**
- Overall plant energetic efficiency: **87-90%**

From Maria Mita (2013) Production of Synthetic Natural Gas based on the Two-Stage Gasifier. Master Thesis, DTU Mechanical Engineering

BGG | VISION

- Fact: **Biomass is a limited resource!**
- Thus there are three thing that matter:

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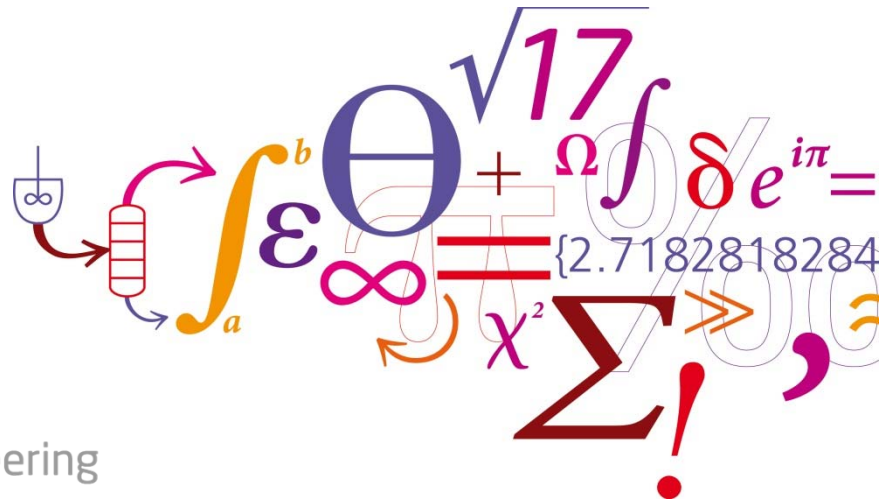
Thank you for your attention



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